Photonic Active Integrated Antennas (PhAIAs) Using Lossless Matching For 2.4-GHz Wireless-over-Fibre Systems

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Abstract: Lossless matching circuits are integrated into PhAIAs used in a 2.4GHz wireless-over-fibre link. The system uses a 220m in-building multi-mode-fibre and results show a greater than 10dB improvement in signal strength and improved throughput.

OCIS codes: (350.4010) Microwaves; (250.7260) Vertical cavity surface emitting lasers.

1. Introduction

Recently, the concept of Photonic Active Integrated Antennas (PhAIAs), where optical devices and antennas are integrated into one low cost circuit has been studied [1]. This allows photonic devices to be easily impedance matched to the non-radiating edge of the antenna where the input impedance varies from a few ohms up to 100's of ohms. Results show that a link using PhAIAs can achieve acceptable throughput and reasonable signal strength and linearity performance. The links use direct modulation employing a VCSEL which has an input impedance, Z_{in}= 37+j0 Ω at 2.4GHz and this can be easily matched by connecting the VCSEL close to the centre of the non-radiating edge. However, the photodiode (PD), used for direct detection, is more capacitive in nature having Z_{in}= 10-j100Ω at 2.4GHz and this cannot be easily matched using the antenna's range of input impedances. One solution is shown in [2] whereby a lossless matching network is used. This paper shows what is believed to be the first example of integration of antenna, matching circuit and optical device in the same low cost module. The matching technique achieves much improved link gain performance across a narrow band which is sufficient for WiFi applications. A bidirectional link including matching circuits in both up and down link is implemented and tested and greater than 10dB improvement in signal strength is obtained.

2. Results

Figure 1(a) shows the complete PhAIA in front view and figure 1(b) shows a zoom in of the matching circuit. Single stub matching is used since this is sufficient for this narrowband application. The circuit is fabricated on low loss substrate with ε_r≈4 and thickness 0.33mm. This matching circuit along with microstrip carrier on which the PD is wire bonded is mounted on the back side of the 2.4 GHz antenna on FR4 substrate with ε_r≈4.5 and thickness 1.5mm.

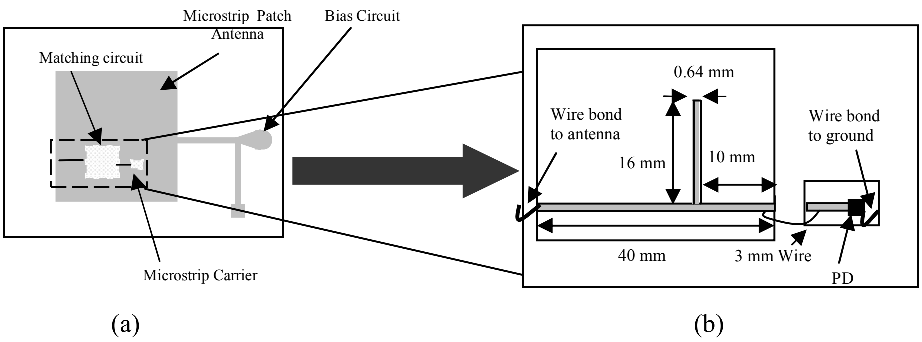
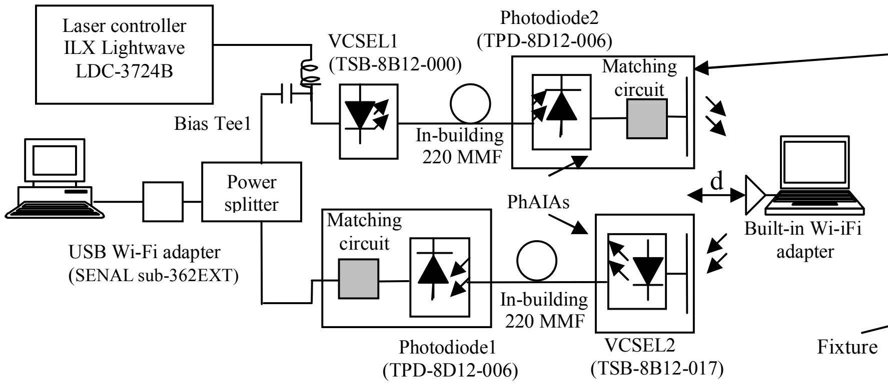


Fig. 1. (a) Layout of the PhAIA with matched PD mounted on backside (b) Matching circuit at the back of the patch (Zoomed in)

Figure 2 (right) shows a photograph of the PhAIA with PD in this setup. A low cost fixture, which can be freely adjusted in X-Y-Z directions, is used for aligning the Multi-Mode Fibre (MMF) to PD. The fully bi-directional link including matching circuits is shown in figure 2.



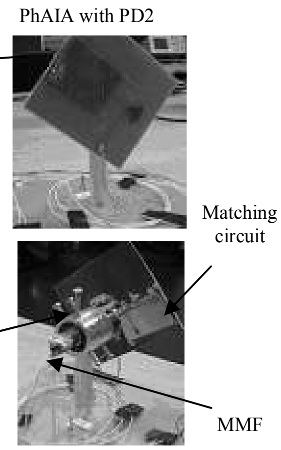


Fig. 2. Diagram of bi-directional link

In figure 2, the USB WiFi adapter (802.11g) is used to simulate an access point from which the WiFi signal can be tapped off. Here, the external antenna of the USB adapter is removed in order that the RF signal can be directly fed into coaxial cable. The power splitter is required to separate the uplink and downlink and the VCSELs and the PDs function as the modulators and demodulators respectively. The laptop is placed at a distance, *d* away from the patch antennas. Then, proprietary software provided by Provision Communications (www.provision-comm.com) a spin-out from the University of Bristol was used to measure the signal strength and the throughput of the link as a function of the distance, *d*.

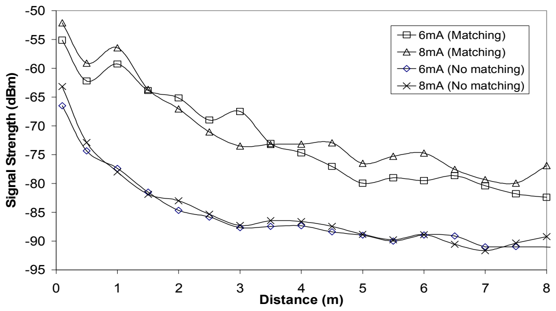


Fig. 3. Signal Strength vs Distance at different VCSEL1 bias currents

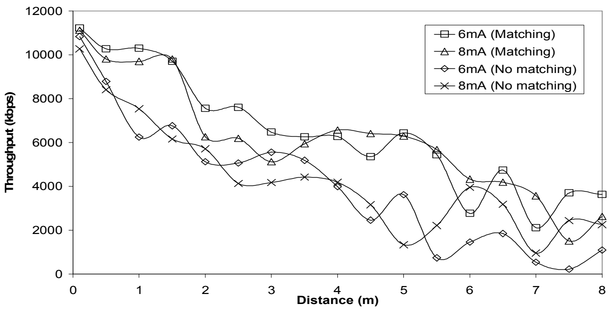


Fig. 4. Throughput vs Distance at different VCSEL1 bias currents

Figures 3 and 4 show that a range of 8m can be obtained with acceptable data rate. It was not possible to obtain data at greater than 8m due to the room size limitation. As can be seen in figure 3, the signal strength can be improved by greater than 10 dB when a matching circuit is used. Figure 4 shows that on average the throughput is also improved, it is believed that fading effects are making the differences less clear at certain distances. Further improvements in performance will be achieved when the splitter is replaced by a low cost, surface mount circulator.

3. Conclusion

The lossless matching technique is applied to a bi-directional WoF link using PhAIAs. The link is demonstrated over 220m of real in-building MMF. Experimental results show an improvement of greater than 10 dB in terms of signal strength and that the connection can be maintained over ranges of 8m without the use of RF amplification.

4. References

[1]. V.Sittakul and M.J.Cryan, "A fully bidirectional 2.4 GHz Wireless-over-fibre system using Photonic Active Integrated Antennas (PhAIAs)", IEEE Journal of Lightwave Technology, vol.25, No. 11, Nov 07.

[2]. E. Ackerman *et al*, "A high-gain directly modulated L-band microwave optical link", IEEE Microwave Theory Tech, 1990, pp. 153-155.